MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 245 June, 1928

Blight and Leaf-spot of Carrot in Massachusetts

IMPERIAL BUREAU
6 MAR 1929
OF MYCOLOGY

By W. L. Doran and E. F. Guba

Blight and leaf-spot of carrot are foliage diseases which occur in Massachusetts with varying degrees of severity according to the character of the season. At the request of growers, the Experiment Station has made a study of the economic importance, causes and control of the two diseases. Results are reported in this bulletin.

Requests for bulletins should be addressed to the

AGRICULTURAL EXPERIMENT STATION

AMHERST, MASS.

BLIGHT AND LEAF-SPOT OF CARROT IN MASSACHUSETTS

By W. L. Doran, Research Professor of Botany and E. F. Guba, Assistant Research Professor of Botany*

Blight and leaf-spot of carrots are not new in Massachusetts. In the very rainy summer of 1920, these diseases were unusually conspicuous and consequently there was a suddenly increased interest in them on the part of some of the growers who wished to know whether or not it would be profitable to attempt to protect carrots against them, and how. As a result, investigations of their real economic importance, cause, and control were undertaken, and the results of these investigations are here presented.

Economic Importance

These diseases may cause loss by reducing the yield of carrots, or the presence of the fungi on the petioles of the leaves may so weaken them as to make the pulling of the roots more difficult, with consequently increased cost of harvesting. According to Clayton (1)[1], the roots are more susceptible to decay following an attack of carrot blight.

The first crop of carrots is planted in Massachusetts as early as the soil can be prepared, and is harvested when about half grown to be marketed in bunches. Neither of these diseases has caused any appreciable loss on early or bunch carrots in this state. However, according to Chupp (2), carrot blight in some sections of the country reduces the market value of carrots sold in bunches by making the leaves unsightly.

The main crop of carrots is planted later, that is, early in June, and is harvested about the last of October to be topped and stored for fall or winter marketing. Blight and leaf-spot are generally present on late carrots and it is usually on the late crop that they have caused loss here.

In Massachusetts, the economic importance of these diseases of carrots is not great in the average season. In the rainy summer of 1922 when the diseases were very conspicuous, the yield per acre at the Market Garden Field Station in Lexington was only 11 per cent below the average. The diseases are not important causes of lowered yields here except in summers of unusually heavy rainfall.

Symptoms

Leaf-spot and blight are often present together on the foliage, so that from the viewpoint of the market gardener they may constitute one disease.

The leaf-spot disease may occur at any point on the leaf although it is most common on the margin. The spots are circular except when their position on the margin of the leaves makes them semicircular. The spots have a diameter of 2 to 5 mm. (about $\frac{1}{16}$ to $\frac{3}{16}$ inches), and they often coalesce to form larger spots. The center of the spot is grayish brown and is usually surrounded by a narrow yellow or straw-colored zone. On the lower surface of the spots a

* The investigation here reported was carried through the first season by W. S. Krout, formerly Assistant Research Professor of Botany.

[1] Numbers in parentheses refer to "Literature cited", p. 278.

grayish weft of the causal fungus is sometimes visible to the naked eye. Leaf-spots on the petioles are more elongated and are slightly darker in color than the spots on the blade of the leaf.

The blight disease appears first as indefinite brown areas with pale yellow centers near the margins of the leaves. Individual teeth of the leaflet turn brown followed by the browning of the leaflet and entire leaf. Sometimes entire leaves turn yellow and then brown and black without the conspicuous presence of the scattered brown areas. Lesions of blight are not as nearly circular nor as sharply defined as are those of leaf-spot. The blight is the more severe of the two diseases and may cause the death of entire leaves. The mass symptoms of blight are more striking than are those of leaf-spot. The foliage of a carrot field in which blight is severe may appear as if burned by heat. Both diseases are much more common on the older leaves of the plants.

Of the two diseases on the main crop of carrots, leaf-spot appears earlier in the season and is generally found during the middle of the summer, and blight does not often appear until late summer. This is probably due principally to differences in susceptibility coincident with growth of the foliage, a point which is further discussed. Although either disease may be found in the absence of any appreciable amount of the other, it is more common for blight to be prevalent following the earlier appearance of leaf-spot in a field.

Causes of Leaf-spot and Blight

Leaf-spot of carrot is caused by the fungus *Cercospora apii carotae* Pass. (3). Blight of carrot is caused by the fungus *Macrosporium carotae* Ell. and Langlois (4).

These fungi have been found constantly associated with the respective diseases in Massachusetts and their pathogenicity here has been established.

Plants Attacked

There is no evidence that the fungi which cause blight and leaf-spot of carrot occur on any other cultivated plants.

Leaves of carrot, parsnip, parsley, and celery were inoculated with *Macrosporium carotae* isolated from carrot foliage, but of the plants inoculated only carrots became infected.

Klotz (5) has shown that *Cercospora apii,* from celery, is not transferable to carrot, and he did not secure infection on celery when he used as inoculum the Cercospora isolated from carrot.

The fungi which cause blight and leaf-spot occur on and have been isolated from both wild and cultivated carrot. Cultivated carrots have been inoculated and infected with these fungi isolated from wild carrots. The wild carrot is a common weed in Massachusetts, and if it grows near a field of cultivated carrots it may serve as a source of infection for the latter.

Relation of Temperature and Moisture to the Germination of Spores of the Fungi

Since the germination of fungous spores is prerequisite to infection, a brief consideration of some of the factors which affect the germination of the spores of these fungi is of interest.

The spores of the blight fungus, *Macrosporium carotae,* were found to germinate well at all temperatures between 61° and 82°F. They germinated best at temperatures between 72° and 75°F. The temperatures most favorable for the germination of the spores of the blight fungus are relatively high.

The spores of the leaf-spot fungus, *Cercospora apii carotae,* germinated best at a temperature of 75° to 78°F.

The spores of both fungi were found to germinate well through a relatively long range of temperature, and it is not likely that summer temperatures are often an important factor affecting infection by these fungi in Massachusetts. In the case of both diseases, there is more likelihood of the weather late in the summer being too cool than too warm for their development.

Water on the leaf is necessary for germination of the spores of the blight fungus, *Macrosporium carotae.* An average of only 6 per cent of these spores germinated in moisture-saturated air as compared with 100 per cent which germinated in water. The leaf must be wet, but these spores germinate quickly and two hours in water is long enough to permit germination.

The spores of the leaf-spot fungus, *Cercospora apii carotae,* germinated well in moist air, but only after they had been previously soaked in water for one or two hours.

These findings are in accord with the field observations to the effect that the severity of these diseases on carrot is usually proportional to the rainfall of the season.

Infection

The germ tubes which grow out of the spores during their germination penetrate the carrot leaves and infection results.

The average length of time between inoculation and the first appearance of the symptoms of disease on the leaves, or the period of incubation, was found to be eight or nine days in the case of the leaf-spot fungus, *Cercospora apii carotae,* and about fourteen days in the case of the blight fungus, *Macrosporium carotae.* The air temperatures during the period of incubation were between 67°F. (nights) and 86°F. (days).

As was anticipated from experiments on germination, it was found that the leaves must be wet and must remain wet for more than two hours for blight infection to occur. If, during the germination of the spores of the blight fungus, *Macrosporium carotae,* on a wet leaf, the leaf became dry and remained so, the germinating spore was killed. A short rain immediately followed by drying sun and wind may result in the death of these spores rather than in their germination. However, carrots are planted so thickly that any rain causes the foliage nearest to the soil to remain wet long enough to permit some infection.

There is an interesting and rather important relation between the age of carrot leaves and the degree of their susceptibility to blight. The oldest and the youngest leaves were removed from plants, placed in moist chambers and inoculated with the spores of the blight fungus, *Macrosporium carotae.* None of these leaves showed any evidence of natural infection, and uninoculated check leaves in moist chambers never became infected. The experiment was repeated five times and in each case three weeks after inoculation the number of blight spots on young and on old leaves was counted. There was an average of twenty-four points of infection on old leaves for each point of infec-

tion on young leaves. The leaves most susceptible to the blight fungus were those which had reached such an age as practically to cease growing.

Blight causes little loss on bunch carrots for they are harvested before the leaves have reached the most susceptible stage. Carrot leaves up to eight weeks of age are relatively resistant to the disease and after that susceptibility increases with age.

Young leaves of carrot are, however, not resistant to leaf-spot, and plants as young as sixteen days old may be infected. But leaf-spot alone is of less importance on the carrot here than is blight, and the symptoms of the former early in the season are rarely conspicuous.

Overwintering of the Fungi Which Cause Blight and Leaf-spot

The spores of the blight fungus, *Macrosporium carotae,* were found to live through the winter in the soil. Spores collected in the field during the winter and spring always germinated. Freezing the spores in ice did not kill them, but rather was followed by an increased percentage of germination.

The mycelium of this fungus was found to be living in carrot refuse in the field as far into the winter as January 15. But attempts to isolate the fungus the following April from mycelium in carrot refuse in the field were not successful.

The leaf-spot fungus, *Cercospora apii carotae,* was found to live through the winter in fragments of carrot leaves in the form of mycelium. Leaves with leaf-spot were buried in the soil in the field in October. The following April the fungus was isolated from the mycelium in these leaves.

The spores of the leaf-spot fungus obtained in the winter and spring from fragments of carrot leaves in the field did not germinate.

Since blight and leaf-spot sometimes occur on the inflorescence of the carrot, the possible relation of carrot seeds to overwintering of the fungi was considered. However, neither of the fungi was found in or on the seeds. Carrot seeds from diseased plants were plated on agar but neither of the fungi developed.

In this connection it may be noted that Klotz (5) did not find on the seeds of celery the closely related fungus, *Cercospora apii,* which causes early blight of this crop.

Since the fungi were not found on carrot seeds, there is probably no reason for market gardeners to disinfect the seeds of carrot for the prevention of blight and leaf-spot. In any case, it is unlikely that seed treatment would materially reduce infection in the field because both fungi are generally present and can winter-over in fragments of diseased carrot leaves in the soil.

Dissemination of the Blight Fungus

In the fall when carrots are harvested, crumbling fragments of decaying leaves which have been lying on the soil form part of the dust in the air. Great numbers of spores of the blight fungus, *Macrosporium carotae,* are present. Slides coated with adhesive were exposed 100 yards from carrots when they were being harvested, and many spores of this fungus were caught upon them. The fungus is doubtless disseminated in other ways, but the spores which are borne by the wind are probably an important means of disseminating the fungus to fields not previously used for carrots.

Laboratory Experiments with Fungicides

Toxicity tests were made by the method of Reddick and Wallace (6).

Bordeaux mixture, 2-2-50, was found to prevent all germination of the spores of the blight fungus, *Macrosporium carotae;* and Bordeaux mixture, 1-1-50, permitted slight germination, only 4 per cent as compared with 100 per cent in the check.

Micro-slides were lightly dusted with a copper dust containing 9.5 per cent monohydrated copper sulfate. These slides were then sprayed with water and dried for twenty-four hours, when drops of water containing the spores of this fungus were placed on them. There was no germination of the spores in the presence of the copper, and the germination of check spores was 100 per cent.

The spores of the leaf-spot fungus, *Cercospora apii carotae,* were found to be even more susceptible to the toxic action of a copper fungicide. Bordeaux mixture 1-1-50, tested by the method of Reddick and Wallace, prevented all germination of these spores.

A copper fungicide which controls blight may be expected to control leaf-spot of carrot.

The effect of sulfur on the germination of the spores of the blight fungus, *Macrosporium carotae,* was determined. Blighted leaves of carrot were dusted with sulfur and placed at controlled constant temperatures, as were also blighted leaves not sulfured. At hourly intervals spores were removed and placed under optimum conditions for germination. It was found that sulfur is not toxic to the spores of this fungus. Even after as much as twenty hours' exposure to sulfur at a temperature as high as 87°F., these spores germinated well, and as well as spores not sulfured. Previous wetting of the spores did not affect their great resistance to the toxicity of sulfur. It is evident from this that sulfur cannot be expected to protect carrot foliage against infection by blight.

In this connection it is of interest to note that the spores of the closely related fungus, *Alternaria solani,* which causes early blight of potato, were found by Doran (7) to be very resistant to the fungicidal action of sulfur.

Spraying and Dusting Experiments in the Field

Field experiments with copper fungicides for the control of blight and leaf-spot of carrot were conducted in five years. In two of them, 1921 and 1922, blight was more than usually severe. In three of them, 1923, 1925, and 1926, there was but little blight.

For lack of more suitable equipment at the time, the spraying was done by carrying a long hose through the carrots from a power sprayer at the end or side of the field. Aside from the inconvenience of this method, the carrots were well sprayed.

In 1921, carrots were sprayed with Bordeaux mixture 4-6-50 at intervals of about eleven days beginning August 22 and ending October 14. The yield per acre was 15 per cent greater on plots sprayed than on plots not sprayed.

In 1922, carrots were sprayed with Bordeaux mixture of the same formula at intervals of about ten days, beginning August 21 and ending October 15. In that year, the yield of carrots per acre was 22 per cent greater on sprayed plots than it was on plots not sprayed.

In 1923, 1925, and 1926, years of little blight, spraying carrots with Bordeaux

mixture 4-4-50 or dusting with a standard copper-lime dust, by the schedule of applications used in the previous years, did not result in any increases in yield over the yield on plots not sprayed or dusted.

According to Chupp (2), some of the growers on Long Island have practiced spraying carrots with Bordeaux mixture for the control of blight, evidently with satisfactory results.

On the basis of the results of the experiments and observations of the writers, however, spraying carrots with Bordeaux mixture is not likely to be profitable in Massachusetts except in the very worst years of blight. Since they cannot be predicted, and since the loss caused by blight and leaf-spot in the average season is not sufficiently great here to warrant much extra expense for control measures, the writers do not recommend that carrots be sprayed every year.

In a rainy season when the indications are that blight and leaf-spot will be severe, the use of a fungicide should be profitable. Since only the older leaves of carrot are susceptible to blight, fungicidal protection of the new growth is less important than in the case of most crops which are sprayed. The application of Bordeaux mixture, on the main crop sown early in June, need not begin before the first week in August in Massachusetts, and later applications need be made only often enough to replace the copper which is lost by weathering, which means usually at intervals of ten days or two weeks. For carrots sown early in May, treatments should begin early in July.

A horse-drawn sprayer naturally cannot be used in such a closely planted crop as carrots. A small compressed-air sprayer lacks in both capacity and pressure. There have recently become available several types of power sprayers designed for or adapted to use on closely planted crops such as carrots. In the absence of such equipment, a hand duster seems to be the only feasible alternative, although the effectiveness of a copper-lime dust for the protection of carrots against blight in years when the disease is severe has not been determined.

Effect of Time of Planting

Because of the relation which was discovered between the age of carrot leaves and their susceptibility to blight, a field experiment was conducted in 1925 with the object of determining the relation of date of planting to the time of the first appearance of blight. This happened to be a season of but little blight.

Carrots were sowed April 17, May 5, May 22, and June 11. All were harvested October 15 and 16.

During August, the blight was more conspicuous on the early sowed carrots, those sowed April 17 and May 5, then on those sowed later. The development of the disease was clearly associated with the approaching maturity of the carrots. A few weeks before harvest, however, blight, although mild, was uniformly present in all plots. Delay in planting postponed the date of the first appearance of blight, but, when measured by the stage of growth of the carrots, the time of onset of the disease was practically the same in all plots.

The disease appeared relatively late in the growth of each plot of carrots, when the roots were already well grown, and no measurable reduction in yield resulted from blight.

At harvest time, the average weight per root of the carrots sown on each

of the several dates was obtained. In the absence of a severe infection of blight, the weights of the roots were affected more by the length of the growing period. The best carrots, considering both size and quality, were those planted May 22. When both the optimum length of the growing period and the relation of age of leaves to susceptibility to blight are taken into consideration, it is probable that, for the late crop, carrots sowed about the last of May or first of June in Massachusetts will do best.

Relation of Fertilizers to Blight

This experiment was undertaken with the object of learning whether or not increasing the amount of nitrogenous or other fertilizer results in an increase in yield of carrots by stimulating blighting plants to the growth of new, and consequently resistant, foliage.

A complete fertilizer, of a 5-8-7 formula, was applied to all plots (0.01 acre in area and in duplicate) at the rate of 1000 pounds per acre before seed was sowed. Other fertilizers, in the amounts per acre named below, were applied as side dressings when the tops were about five inches high.

Blight was only mild and there were no visible differences in growth of tops or in degree of blight infection in the several plots.

The carrots were harvested and weighed at the end of the season. The yields per unit area, expressed as relative numbers, with 100 as an index of the yield on plots which received no side dressings of additional fertilizer, were as follows: with 275 pounds nitrate of soda, yield 106; with 500 pounds acid phosphate, yield 102; with 140 pounds sulfate of potash, yield, 96.

The differences in yields are too small to be significant. In the absence of sufficient blight for the original purpose of the experiment, the effect of the disease on yield was not influenced by the fertilizers.

Control Measures

Since these fungi pass the winter in and on the soil in the refuse of the preceding crop, the possibility of partial control by crop rotation and by deeply plowing under or destroying the blighted tops after harvest is suggested.

Wild carrots should not be allowed to become common near fields where carrots are to be grown, for the fungi which cause blight and leaf-spot are present on these weeds.

There is no reason to disinfect carrot seeds to prevent these diseases.

Carrots planted as late as will permit them to reach marketable maturity are not likely to be affected by blight as severely as carrots planted earlier.

These diseases have not often been severe enough in Massachusetts to make the use of fungicides profitable. It is not recommended that carrot growers here make a general practice of spraying or dusting carrots. If there is continued rainy weather and the grower desires to spray for the protection of carrots, he should use Bordeaux mixtures of the usual formula or dust with a standard copper-lime dust such as is used on celery, beginning about August 15 and making applications at such intervals as are necessary to replace the material which has been washed off the older leaves.

Summary

Blight of carrots, caused by *Macrosporium carotae,* and leaf-spot of carrots, caused by *Cercospora apii carotae,* usually occur together in Massachusetts. Blight is the more important here.

These diseases usually cause no measurable loss on carrots pulled young to be marketed in bunches. On late carrots, they cause no appreciable loss in yield in dry summers and moderate to heavy loss in yield in rainy summers.

Factors affecting spore germination and infection are considered. In Massachusetts, summer temperature is a less important factor influencing development of these diseases than moisture.

The oldest leaves of carrot have been found to be most susceptible to blight.

It has been found that both fungi pass the winter on dead leaves of carrots in or on the soil. No evidence has been found that either of these fungi is carried on the seeds of carrots.

Both fungi are very susceptible to the fungicidal action of copper. Laboratory and field experiments with fungicides are described. It is not recommended that carrots be generally sprayed in Massachusetts, but in rainy summers when blight was severe increases in yield resulted from spraying with Bordeaux mixture.

The latest sowings of carrots are least affected by blight because of the relative resistance to infection of younger leaves, and unfavorable temperatures prevailing late in the growth of the crop.

Literature Cited

1. Clayton, E. E. Carrot rot information. Market Growers' Jour. 38: 15. 1926.
2. Chupp, Charles. Macrosporium leaf-blight of carrot, *in* Manual of vegetable-garden diseases. New York. 1925.
3. Passerini, Giovanni. *Cercospora apii* var. *carotae* Atti, R. Accademi dei Lincei. Anno 286. Memorie della Classe di Scienze Fisiche, Matemiche e Naturali. Serie 4, vol. 6, p. 469. 1889.
4. Ellis, J. B. and A. B. Langlois. *Macrosporium carotae, in* New species of Louisiana fungi. Jour. Mycology 6: 35-37. 1890.
5. Klotz, L. J. Studies on Michigan celery diseases, 2. A study of the early blight fungus, *Cercospora apii* Fres. Mich. Agr. Expt. Sta. Tech. Bul. 63. 1923.
6. Reddick, Donald and Errett Wallace. On a laboratory method of determining the fungicidal value of a spray mixture or solution. Science 31. 798. 1910.
7. Doran, William L. Laboratory studies of the toxicity of some sulphur fungicides. N. H. Agr. Expt. Sta. Tech. Bul. 19. 1922.

Publication of this document approved by the
Commission on Administration and Finance.

4 M-10-28. No. 3638